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# MINERAL COMMODITY REPORT: DIATOMITE

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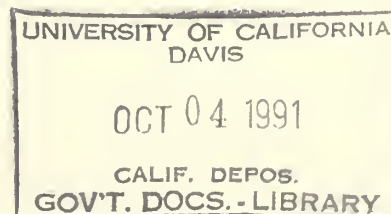
SPECIAL PUBLICATION 111  
**MINERAL COMMODITY REPORT**  
**DIATOMITE**

**1991**

BY

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# TABLE OF CONTENTS

Introduction .....	1
<b>PART I: UNITED STATES AND WORLDWIDE .....</b>	<b>2</b>
Table 1. Diatomite sold or used by producers in the United States .....	2
Table 2. Diatomite sold or used, by major use .....	2
Table 3. Average annual value per metric ton of diatomite by major use .....	2
Table 4. U.S. exports of diatomite .....	2
Table 5. Diatomite: World production by country .....	3
<b>PART II: CALIFORNIA .....</b>	<b>4</b>
Origin of Diatomite .....	4
Localities in California.....	6
Lompoc, Santa Barbara County .....	6
Lake Britton, Shasta County .....	6
Casmalia, Santa Barbara County .....	11
Hames Valley near Bradley, Monterey County .....	12
San Joaquin Valley, Kern County .....	12
Poverty Hills Deposit, Inyo County .....	12
Long Valley, Mono County .....	12
Long Valley, Lassen County .....	13
Boca Reservoir, Nevada County .....	13
Copco Reservoir Deposits, Siskiyou County .....	13
Piute Valley, Needles, San Bernardino County .....	13
White Christmas Deposit near Ocotillo, Imperial County .....	13
Northeastern California including Modoc, Lassen, eastern Siskiyou and NE Shasta counties .....	14
Other Deposits .....	16
Knights Ferry, Stanislaus County and Friant, Fresno and Madera counties .....	16
Getty Oil Diatomite Project near McKittrick, Kern County .....	16
Reserves .....	17
California Production .....	17
Utilization and Production .....	17
Table 6. Comparison of U.S. diatomite production and demand 1963-1983, 1990 and 2000 .....	19
Markets .....	20
Mining .....	20
Beneficiation .....	20
Events, Trends and Issues .....	21
Acknowledgments .....	21
References .....	23
Appendix .....	25





# MINERAL COMMODITY REPORT

## – DIATOMITE–

### INTRODUCTION

United States sales of processed diatomite decreased slightly in 1989 to 617,000 metric tons valued at \$137 million, according to the Bureau of Mines, U.S. Department of the Interior. Seven companies processed diatomite at 11 plants in five states. California continued to be the leading state followed by Nevada, Washington, Oregon, and Arizona. Major domestic producers were Manville Products Corp., with operations at Lompoc, California; Grefco Inc., Dicalite Division, at Lompoc and Burney, California, and Mina, Nevada; Eagle-Picher Minerals Inc. at Sparks and Lovelock, Nevada; and Vale, Oregon; and Witco Corp., Inorganic Specialties Division, at Quincy, Washington. Other producers were Whitecliff Industries, Mammoth, Arizona; CR Minerals Corp., Fernley, Nevada; and Oil-Dri Production Co., Christmas Valley, Oregon.

Apparent domestic consumption of processed diatomite in 1989 decreased slightly to 481,000 metric tons. The major use of diatomite is in filtration to separate suspended solids in liquids. In 1989, domestic and export sales of filter-grade diatomite were 441,000 tons, slightly more than in 1988. Sales of diatomite as a filler, the second largest use, were 90,000 tons, about 15% less than in 1988.

The average unit value of sales for processed diatomite in 1989 was \$222.00 per ton. This was slightly less than in 1988. U.S. exports of processed diatomite were 137,000 tons, about 7% less than in 1988. Average unit value was \$302.00 per ton compared with \$268.00 per ton in 1988. Diatomite was exported to 67 countries. The following countries combined received 37% of the total exported: Japan, 16,600 tons; Australia, 12,600 tons; the Federal Republic of Germany, 11,100 tons; and the United Kingdom, 10,100 tons. U.S. exports represented 22% of domestic production. Imports of diatomite were 838 tons, 84% of which was supplied by Mexico.

World production was estimated to be 1.8 million tons in 1989. The United States remained the world's leading producer followed by Romania, the USSR, and France. These four countries accounted for 75% of world production.

Prepared in Branch of Industrial Minerals and Branch of Data Collection, U.S. Bureau of Mines, April 13, 1990.

## PART 1: UNITED STATES AND WORLDWIDE

TABLE 1. *Diatomite Sold or Used by Producers in the United States (Metric tons and dollars in thousands)*

Use	1985	1986	1987	1988	1989
Domestic production (sales)	676	570	596	629	617
Total value of sales (\$)	127,030	128,362	134,239	143,774	136,754

TABLE 2. *Diatomite Sold or Used, <sup>1</sup>by Major Use*

Use	1985	1986	1987	1988	1989
Fillers	21	17	16	17	15
Filtration	66	67	69	69	71
Insulation	01	03	02	02	03
Other <sup>2</sup>	12	13	13	12	11

<sup>1</sup> Includes exports.

<sup>2</sup> Includes absorbents, additives, and silicate admixtures.

TABLE 3. *Average Annual Value per Metric Ton<sup>1</sup> of Diatomite, by Major Use*

Use	1987	1988	1989
Fillers	\$249.71	243.49	233.68
Filtration	\$239.86	244.34	237.61
Insulation	\$120.95	121.12	104.61
Other <sup>2</sup>	\$132.87	140.16	132.89
Weighted Average	\$225.06	228.56	221.58

<sup>1</sup>Based on unrounded data.

<sup>2</sup>Includes absorbents, additives, and silicate admixtures.

TABLE 4. *U.S. Exports of Diatomite (Metric tons and dollars in thousands)*

Year	Quantity	Value <sup>1</sup>
1986	119	\$32,180
1987	126	33,076
1988	147	39,374
1989	137	41,290

<sup>1</sup>U.S. Customs.



TABLE 5. Diatomite: World Production by Country<sup>1</sup> (Thousand metric tons)

COUNTRY	1985	1986	1987	1988	<sup>P</sup> 1989
Algeria	3	04	<sup>E</sup> 4	<sup>E</sup> 4	4
Argentina	10	14	5	7	7
Australia	8	9	10	11	11
Brazil (marketable)	<sup>R</sup> 18	<sup>R</sup> 20	<sup>R</sup> 16	<sup>E</sup> 20	20
Canada	4	4	4	4	4
Chile	2	3	3	3	3
Costa Rica	..	..	..	..	..
Denmark: <sup>2</sup>					
Diatomite <sup>3</sup>	6	6	6	6	6
Molar	72	73	<sup>E</sup> 66	<sup>E</sup> 66	66
France <sup>E</sup>	<sup>3</sup> 270	260	250	250	250
Germany, Federal Rep. of	48	49	47	<sup>E</sup> 48	48
Iceland	29	23	<sup>E</sup> 25	<sup>3</sup> 25	25
Italy <sup>E</sup>	30	27	28	28	28
Kenya	3	1	1	1	1
Korea, Republic of	54	55	65	72	70
Mexico	46	36	35	35	35
Peru	15	<sup>R</sup> 9	21	15	15
Portugal	2	2	<sup>E</sup> 2	<sup>E</sup> 2	2
Romania <sup>E</sup>	300	300	280	280	260
South Africa, Rep. of	1	2	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>
Spain	96	128	<sup>E</sup> 100	<sup>E</sup> 100	100
Thailand	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>
Turkey <sup>E</sup>	3	3	3	<sup>R</sup> 1	1
U.S.S.R. <sup>E</sup>	245	250	255	260	260
United Kingdom <sup>E</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>	footnote <sup>4</sup>
United States <sup>5</sup>	576	570	596	629	<sup>3</sup> 617
<b>TOTAL</b>	<sup>R</sup> 1,841	<sup>R</sup> 1,848	1,822	1,672	1,838

<sup>E</sup> Estimated. <sup>P</sup> Preliminary. <sup>R</sup> Revised.

<sup>1</sup> Table includes data available through April 9, 1990.

<sup>2</sup> Data represent sales.

<sup>3</sup> Reported figure.

<sup>4</sup> Less than 1/2 unit.

<sup>5</sup> Sold or used by producers.

## PART II: CALIFORNIA

### ORIGIN OF DIATOMITE

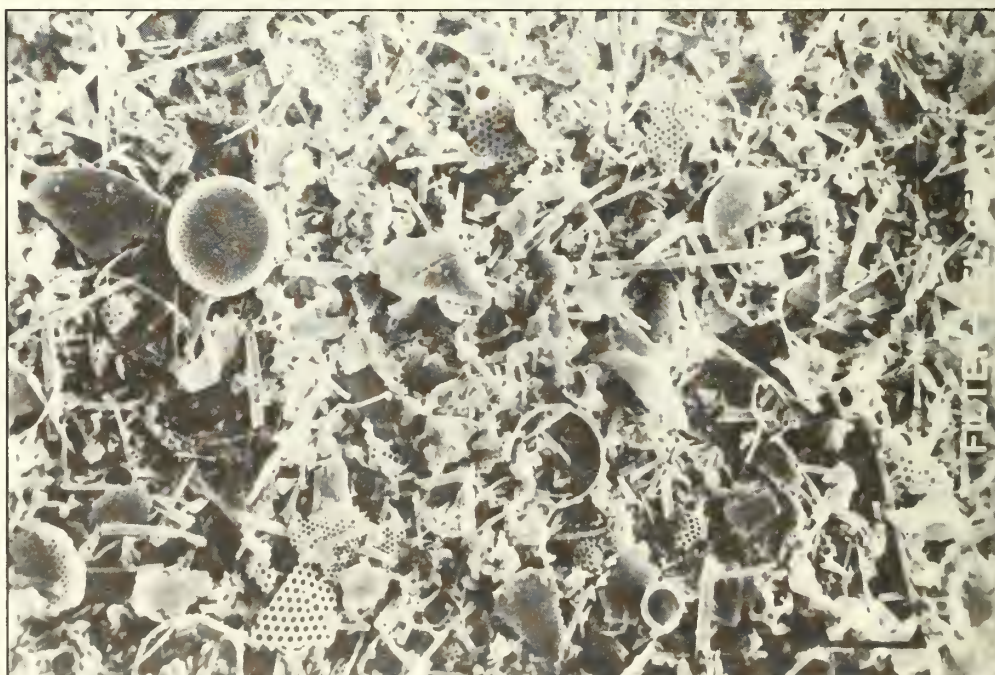
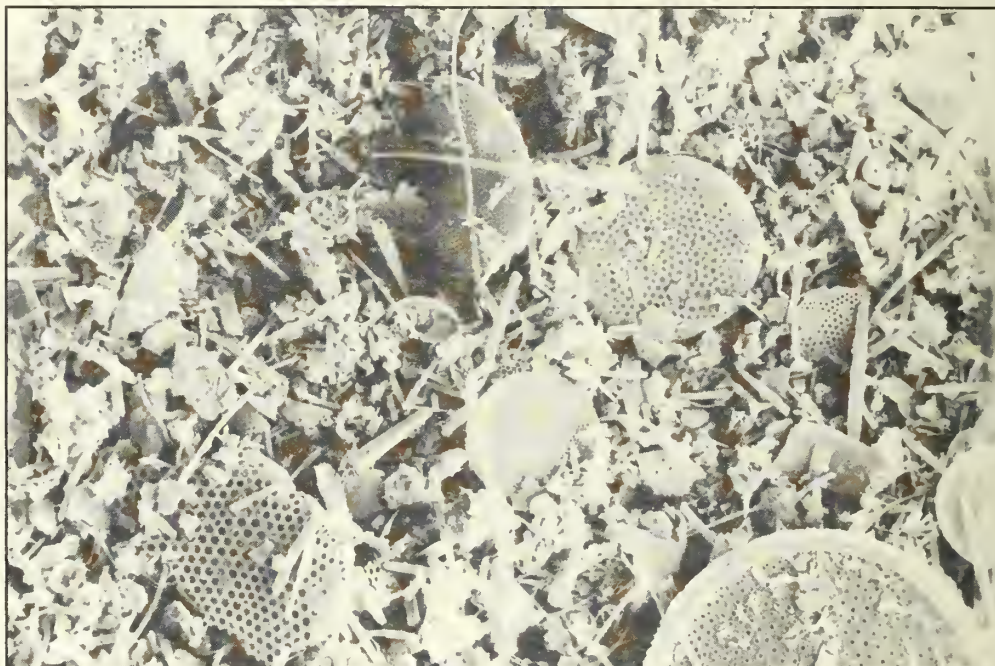
Diatomite is a sedimentary rock made up of the skeletal remains of microscopic plants called diatoms. Diatoms are one-celled golden brown algae which belong to the class *Bacillariophyceae*, and like other plants, they use sunlight for growth through photosynthesis. Thousands of diatom species have been identified and they can be found in virtually all environments which provide water and sunlight. Under ideal conditions, diatoms flourish and multiply, forming enormous floating colonies that move with water currents. These tiny plants secrete a framework and outer shell, called a frustule, made of opaline silica (Photo 3). When diatoms die, the frustules accumulate on the ocean bottom and form a diatomite deposit (Photos 1 and 2).

The soft parts of the diatom form a fatty oil that decomposes or becomes petroleum when buried. In fact, many of the oil fields of California are closely associated with large deposits of shale in which diatoms are either abundant or were once obviously present. This association has led to the theory that at least some of the oil originated from the oily globule found in each living diatom (Hanna, 1951).

In the marine environment, diatoms are most abundant in regions of upwelling where deep, cold, nutrient-rich ocean water is brought up from the ocean floor to the surface by winds and currents. A world map showing highly productive areas of living matter in the Pacific Ocean illustrates bands at both poles including the Antarctic coast, the Aleutian Islands off Alaska, and the North American

coast from northern British Columbia, Canada to the southern tip of Baja California, Mexico (Gross, 1972, Fig. 17-2; Barron, 1987, Fig. 7-1). In the geologic past, as well as the present, coastal California was a part of this region of upwelling cold water. Prolific production is going on today off the central Oregon coast and within the Gulf of California (Barron, 1987).

Nonmarine diatomite is typically formed in a lakebed and pure deposits result if little or no detrital sediment is washed with the



Photos 1 and 2. Lompoc marine diatomite, 250X scanning electron micrograph. (Photo courtesy of Manville Products Co.)



diatom frustules. In addition, nonalkaline conditions are necessary for the preservation of a diatomite deposit because during deposition and subsequent diagenesis, the solubility of silica (opal) increases abruptly at a  $\text{pH}$  greater than 9 (Krauskopf, 1959). For example, Lohman (1960) reports that the Late Cenozoic Furnace Creek Formation in Death Valley contains claystone that is locally enriched in sodium and calcium borates. No diatoms are preserved in this claystone, although adjacent limestone does contain diatoms. The limestone's impermeability to alkaline pore waters protected the diatoms; diatoms within the claystone were not protected and dissolved following deposition.

The proliferation of diatoms in bodies of water is associated with an increase of soluble nutrients, specially silica, nitrogen and phosphorus. All the commercial diatomite deposits in

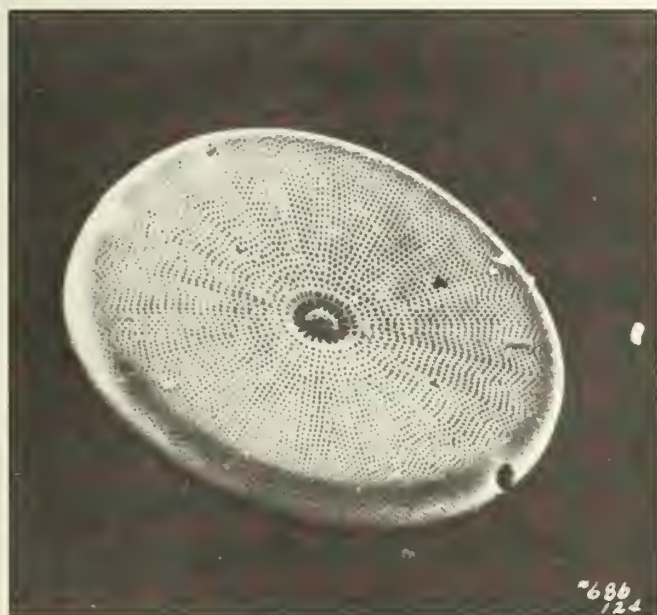


Photo 3. *Arachnoidiscus ornatus*. A single, disc-shaped diatom found in the Lompoc deposits. (Photo courtesy of Manville Products Co.)

California are associated with volcanic eruptions, and volcanic ash is a very common constituent in diatomaceous rocks. However, Calvert (1966) has shown that prolific diatom growth can occur in the absence of volcanic activity when normal quantities of silica are dissolved in the water and circulation is maintained to replace silica used by the diatoms. Trace quantities of boron, which is reported to be an essential element for diatom growth (Kadey, 1983, p. 677), are also relatively common in both seawater and argillaceous sediments (Goldschmidt, 1954). The ultimate source of both silica and boron associated with diatomite is probably volcanic eruptions, although in alpine settings, glacial flour can be a

source of silica; the silicate minerals in glacial flour have been ground to a fine powder, thereby increasing the solubility of the silica (Cleveland, private communication, 1989; Durham, 1973, p. 193).

Marine diatoms first appear in the fossil record during the late Cretaceous period. Marine diatomite and diatomaceous sediments are common in the California Coast Ranges and coastal areas from Point Reyes to Orange County. Marine diatomites are not found in other parts of the western United States. Nonmarine diatoms occur in rocks as old as late Eocene but most are late Tertiary or Quaternary in age. These deposits are widespread in the western United States, especially northeastern California, northern Nevada, eastern Oregon, southwestern Idaho, central Washington (Barron, 1987) and southern Arizona. Prior to these times, diatoms are not present in the fossil record. Either diatoms had not evolved at all or the opaline frustules were not preserved in the fossil record.

The delicate shell or frustule which gives diatomite so many of its unusual properties is composed of opal, an amorphous mineral composed of silica and up to 10% water. Opal is metastable and will in time change from hydrous opal ( $\text{SiO}_2 \cdot n\text{H}_2\text{O}$  - opal A) to anhydrous opal (crystalite - tridymite called opal CT) to quartz, the stable end-member of this series. Temperature appears to be the major factor controlling silica phase transformation. The change from opal A to opal CT occurs at approximately  $45^\circ$  to  $50^\circ\text{C}$  ( $113$  to  $122^\circ\text{F}$ ), although impurities in the diatomite may cause this change at somewhat lower temperatures. The change from opaline diatomite to chert (quartz) with increasing temperature and pressure has been studied in the oil fields of southern California (MacKinnon, 1989). The progression is from hydrous silica to anhydrous silica to quartz ( $\text{SiO}_2$ ) (MacKinnon, 1989). The most dramatic change occurs in the transformation of soft, punky diatomaceous rocks (opal A) to chert, porcelainite or siliceous mudstone (opal CT) which is typically hard and brittle. The change is accompanied by a sharp decrease in porosity and an increase in grain size and bulk density.

These changes are illustrated in Figure 1 for two localities with different geothermal gradients. An important difference between these two fields is the geothermal gradient. In the Santa Maria Basin, the gradient is  $2.7^\circ\text{F}/100$  feet of depth so that the opal A-opal CT transition is reached at around 2,000 feet of depth. In the Ventura Basin, the gradient is much lower at  $1.37^\circ\text{F}/100$  feet of depth so that this transition temperature is reached at around 4,000 feet of depth. The transitions take place at shallower depths in areas with high heat flow.

High pressure is another factor in the opal A to opal CT transition, although it is less important than temperature. Under high pressure, the delicate structure of the diatom frus-

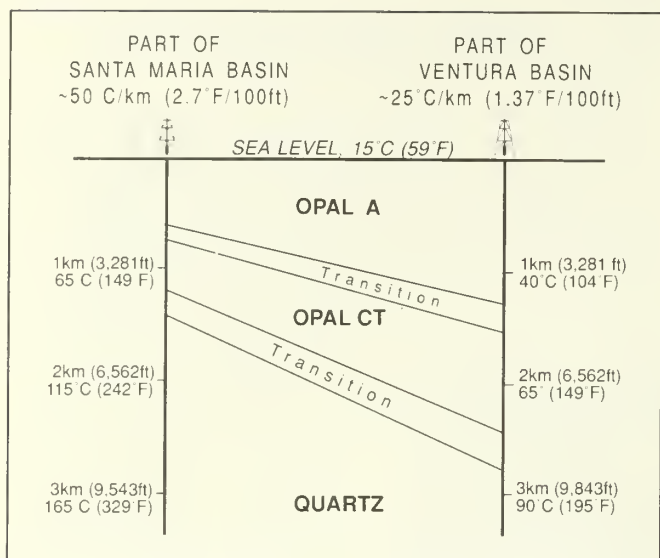


Figure 1. Transition of opal varieties with geothermal gradient (MacKinnon, 1989)

tule and the water can be driven out to form the more dense minerals cristobalite and tridymite which together compose opal CT. High pressure results from the weight of overlying material or deformation such as folding or faulting. A final factor in preserving the unchanged physical characteristics of the diatom frustule is geologic age. Older rocks are much more likely to have been subjected to high temperatures and pressure than younger ones. Given enough geologic time, the alteration sequence opal → cristobalite → tridymite → quartz will take place. Except for quartz, all of these are temporary or metastable forms of the stable end-member.

## LOCALITIES IN CALIFORNIA

The largest diatomite deposits in California are the upper Miocene and Pliocene marine deposits found in the Coast Ranges of central California and the Peninsular Ranges of southern California. These deposits extend discontinuously from Point Reyes, Marin County to San Onofre in northernmost San Diego County (Figure 2). Large areas of these rocks have been lost to mineral development due to urbanization, especially in Ventura, Los Angeles and Orange counties in southern California. Another group of potential deposits is the diatomaceous marine shales of the Eocene, Paleocene and Cretaceous formations found on the west side of the San Joaquin Valley from Stanislaus County to southern Fresno County. A smaller but important group is the freshwater deposits found in many parts of the state (Photo 4). The largest reserves of freshwater diatomite are in Shasta, Siskiyou, Modoc and Lassen counties. In addition, marine diatomite deposits are present in the eight channel islands located in both the Peninsular and Transverse Ranges. The largest deposits are on the Santa Catalina, San Clemente, Santa Cruz and Santa Rosa islands.

## Lompoc, Santa Barbara County

The Lompoc deposits are the largest source of diatomite currently being exploited in the world (Figure 3). Three commercial quarries occur in marine sediments of the Sisquoc Formation of upper Miocene to lower Pliocene age. The foothills of the Santa Ynez Mountains south of Lompoc Valley and the Santa Rita Hills include an area that contains the most extensive deposits of high-purity diatomite in the world. (Oakeshott, 1957). These deposits are in the lower part of the Sisquoc Formation in a complex syncline trending slightly north of due west. Various parts of the Sisquoc Formation are discontinuously exposed at the surface for more than 15 miles in a series of closely-spaced folds. Bed thicknesses range from several inches to over 40 feet; the dip of the beds ranges from flat to nearly 60 degrees.

The quarries were first developed around 1878 on a very limited basis, and full-scale mining began after World War II. Production expanded as marketing increased sales of each product.

The two commercial operators in this area are Manville Products Co. and Grefco Inc (Photo 5). Both produce a broad range of filter aids, fillers, insulating materials, abrasives, absorbents and other products. Both operations have been described by others (Taylor, 1981; Clark, 1978; Cleveland, 1966; and Oakeshott, 1957). Marine deposits contain a wider variety of diatom shapes and sizes than do freshwater deposits and therefore, a broader range of products and grades within one product can be produced. Modern processing techniques have been improved to the point where diatoms can be separated by species.

## Lake Britton, Shasta County

The Pit River diatomite province contains large deposits of freshwater diatomite covering over 20 square miles. These

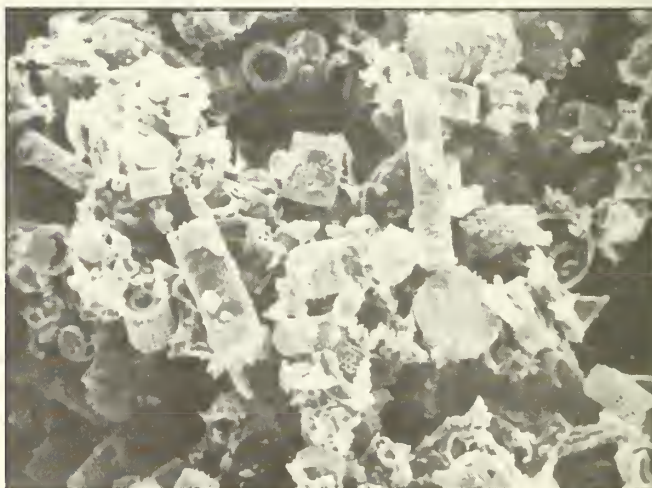


Photo 4. Freshwater diatomite, 500x scanning electron micrograph. (Photo courtesy of Manville Products Co.)



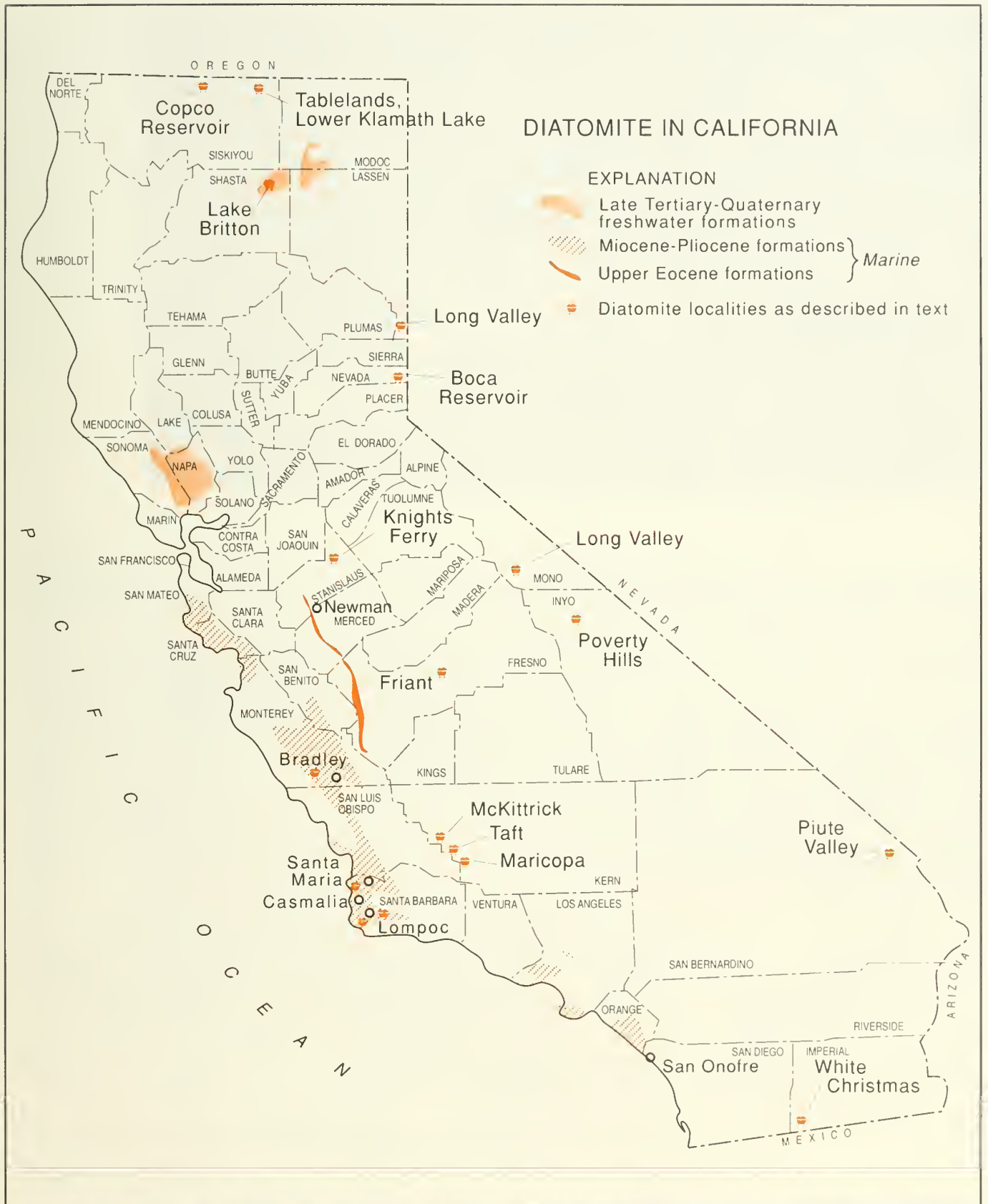


Figure 2: Map of California showing the generalized distribution of diatomite and diatomaceous formations (Modified from Oakeshott, 1957).

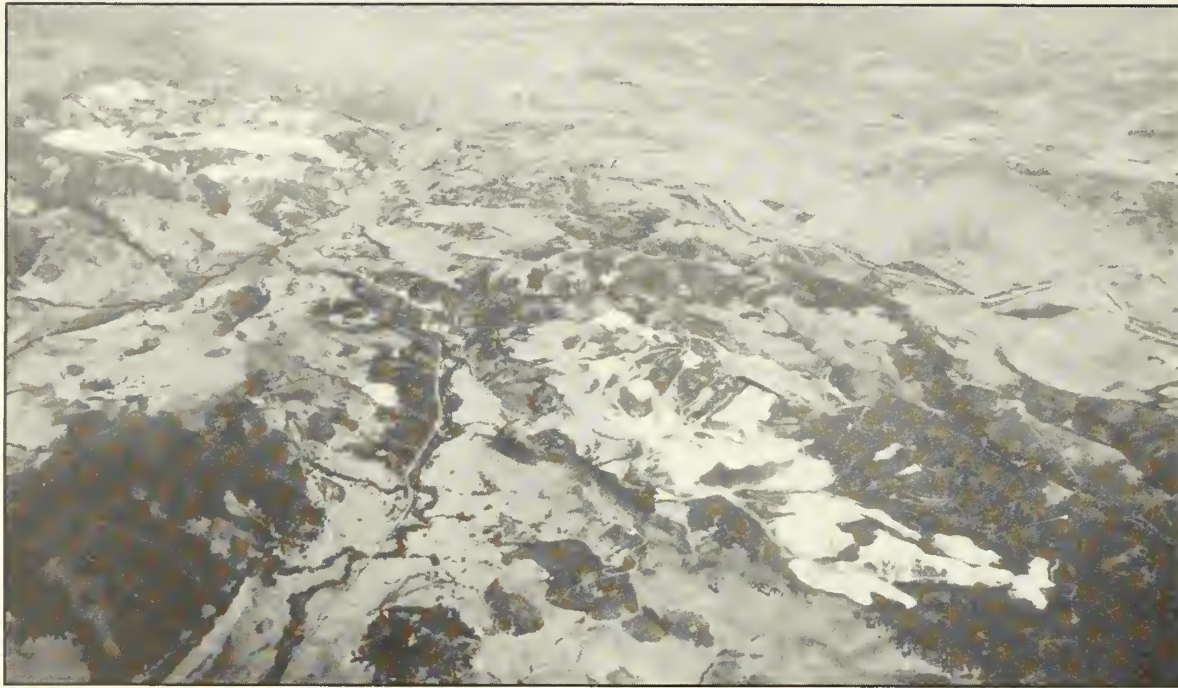


Photo 5. The White Hills diatomite mines near Lompoc; Grecco Inc. in the foreground and Manville Products Co. in the background. (Photo courtesy of Grecco Inc.)

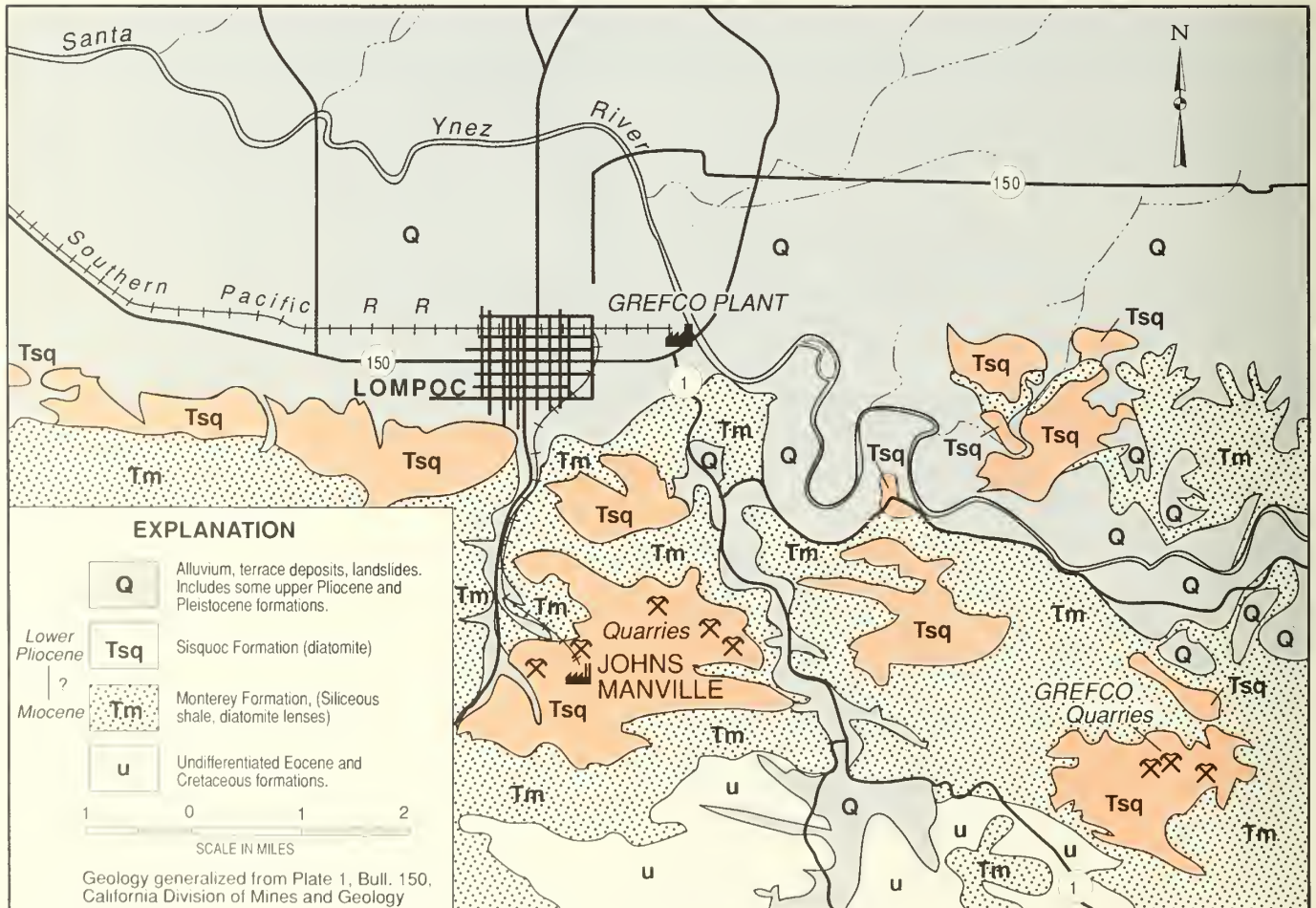


Figure 3. Geology of the Lompoc area, Santa Barbara County, showing distribution of the diatomite-bearing Sisquoc Formation (Dibblee, 1950).



deposits are located in Shasta County, California, about 50 miles northeast of Redding (Figure 4). Burney and Fall River Mills are the nearest towns. The deposits are exposed for 15 miles on either side of the Pit River extending from near Hat Creek on the east to a point located 2 miles west of Rock Creek. The diatomite deposits were identified around 1900 and staked as mining claims between 1921 and 1922. Dicalite Division became active in the area around 1952 relocating claims and conducting exploration drilling. In the mid 1960's, Dicalite was acquired by Grefco Inc., which continued drilling into the 1970's. The active plant and quarry were opened in 1986.

The configuration of the surface exposure of the Pit River diatomite deposit is very similar to the present day manmade Lake Britton (Photo 6). This suggests that the deposit formed in a lake behind a natural obstruction to the middle Pliocene Pit River drainage system. Regional geology suggests that

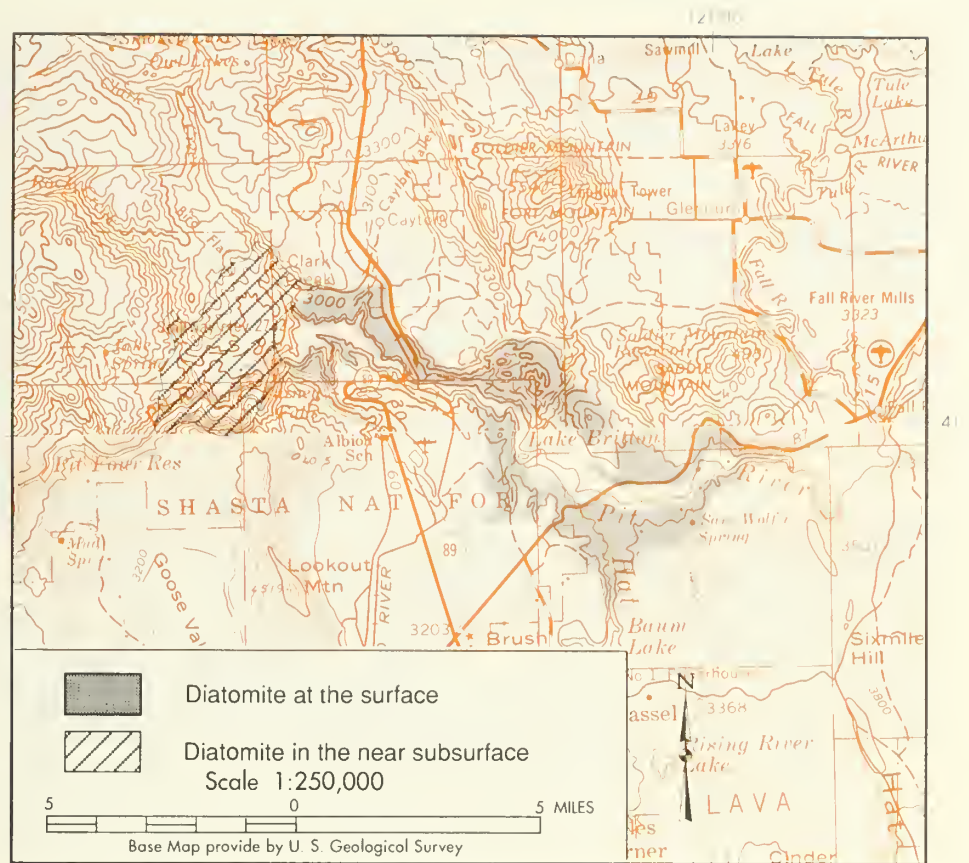


Figure 4. Lake Britton diatomite deposits (Smith, 1980; Gay and Aune, 1958; Lydon and others, 1960)



Photo 6. The Dicalite quarry (Grefco) near Lake Britton, Shasta County. (Photo by John L. Burnett.)





Photo 7. The working face of the Dicalite quarry (Grefco) near Lake Britton, Shasta County. The man is pointing to a 2-inch layer of sandy detritus which will be selectively removed during mining. (Photo by John L. Burnett.)

the obstruction could have been a volcanic flow or some other volcanic-related feature. The Pit River diatomite deposits are located on the boundary between the Cascade Range and Modoc Plateau, both of which are volcanic provinces. The basement rocks for the Pit River diatomite have been identified as Miocene mud flows, basalt, and andesite (Aune, 1964). The cap rocks are basalts of late Pliocene age (Meisenger, 1975-1978). Sandwiched between these volcanic rocks are sediments of middle to late Pliocene or Pleistocene age, consisting of diatomite, sand, and clay (Photo 7). Lateral and vertical erosion by the Pit River has cut through the overlying cap exposing the sediments over a large area.

The diatomite at Lake Britton is chemically very pure even when compared to select grades of material from Lompoc. The deposit is massive and remarkably uniform in qual-



Photo 8. The Airox Mine near Casmalia. High quality pozzolan and structural lightweight aggregate were produced from this deposit of petroleum-bearing diatomite. (Photo by John L. Burnett.)

ity both laterally and vertically. The material mined by Grefco Inc. is extremely pure, being deposited in a former lake embayment which had little clastic debris carried into it by surface streams (Smith, 1980). The beds are flat-lying and range in thickness from 1 inch to several feet. The diatomite beds are as much as 200 feet thick, but pinch out along the margins of the deposit.

Four miles southeast of the Grefco quarry, diatomite is mined by American Resources Inc. and used as the silica-rich portion of feed for a cement plant north of Redding, Shasta County. This material contains more clastic sand and clay but this does not pose a problem as long as the mined material is chemically uniform. Limestone, silica and alkalis are blended to produce a uniform product during firing in the cement kiln.

#### **Petroleum-bearing diatomaceous shale, near Casmalia, Santa Barbara County**

The Casmalia-Santa Maria area of Santa Barbara County and adjoining San Luis Obispo County has been an important source of petroleum for many decades. Late Miocene and Pliocene diatomaceous shales are abundant in the area and petroleum-saturated diatomaceous shales are common. Two commercial operations have been carried out in the past to develop this resource. Beginning in 1941, the Airox Co. began producing high quality pozzolan and lightweight aggregate for concrete by open burning shale in long piles or windrows (Photo 8). The burning temperature was controlled by

blending oxidized, weathered material from near the ground surface with petroleum-saturated material mined at depth. Early in the 1970's, air pollution controls required cessation of open burning and the operation was closed. Later in that decade, a vertical reverberator kiln was built in an attempt to solve the air pollution problems and produce equivalent products. However, this operation never reached full production and finally closed. The equipment, including the furnace, are still on the property.

The N.T.U. mine was developed and began operation in 1922 to recover petroleum from oil-saturated diatomaceous shale. Rock was mined, retorted in a crude, open grate and the petroleum drained away. Although historically interesting, production was minor.

Both deposits are in the Sisquoc Formation of Mio-Pliocene age and are situated within a complex anticline with other closely-spaced folds along its limbs. At the Airox mine, beds are 1-inch to 1-foot in thickness, and dip gently to the north-northeast. There are several sets of well-developed jointing which tend to obscure the bedding planes. Oxidized diatomite exposed at the surface is whitish brown while unoxidized petroleum-saturated diatomite is dark brown to nearly black. The uppermost surface of the quarry is a red cap rock of burned shale formed by natural burning of the petroleum-bearing rock. The N.T.U. mine shows the same color relationship and has a burned cap rock nearby.

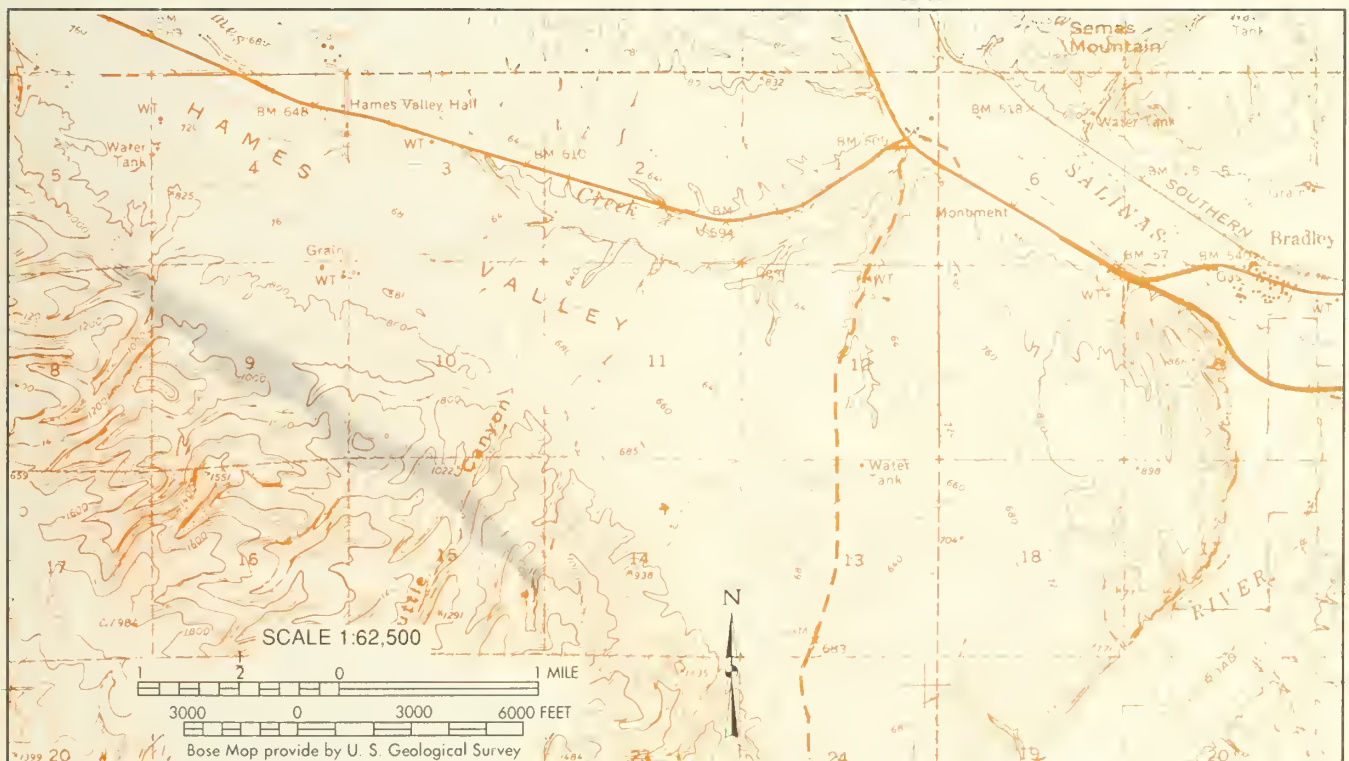


Figure 5. Hames Valley diatomite (Hart, 1966)



### Hames Valley near Bradley, Monterey County

A layer of diatomite up to 500 feet thick has been mined in southern Monterey County near U.S. Highway 101 (Figure 5). The layer is near the top of the Monterey Formation and is in the northeast limb of a syncline. Mining and prospecting took place along 3 miles although the layer extends beyond these limits. The diatomite trends northwesterly and dips 40 to 60 degrees to the northeast. Limited production occurred between 1906 and 1942 and probably terminated because the location is distant from the largest markets and the steep attitude of the layer required expensive underground mining methods (Hart, 1966).

The diatomite beds vary from white to tan and contain occasional thin interbeds of chert and siliceous shale especially near the bottom. At the bottom of the layer, diatomite grades into siliceous shale and chert of the Monterey Formation. Pliocene sands and conglomerates unconformably overlie the diatomite.

### Diatomaceous shales on the west side of the Southern San Joaquin Valley, Kern County

Quarries located in western Kern County produce absorbents from various members of the Monterey Formation. The raw materials are buff-colored, thinly- to thickly-bedded diatomaceous shales associated with siliceous shale (porcellanite) and chert. The cherty portions must be avoided or removed as waste. The raw material is processed into cat litter and sweeping compounds.

Excel-Mineral Co. operates the Taft Quarry and Lowe's Southern California Clay Co. operates the Lowe's Quarry near Maricopa. Although each quarry is in a different stratigraphic member of the Monterey Formation, all have similarities. All are diatomaceous, although the most important component is smectite (montmorillonite) clay. Diatomite from McKittrick Quarry, formerly operated by Excel Mineral Co., contains a high percentage of partially devitrified volcanic glass which is the source of the smectite clay. Excel is mining from the McClure member of the Monterey Formation and Lowe's uses the Gould member of the Monterey Formation. In both quarries, the bedding is moderately folded and faulted.

### Poverty Hills Deposit, Inyo County

A small deposit on the east slope of the Poverty Hills is a lacustrine formation of probable Pleistocene age. A 4-foot bed of nearly pure diatomite is exposed for 1,750 feet and forms part of a west-tilted fault block. The diatom genera *Epithemia* and *Fragilaria* predominate. The deposit is in Sections 23 and 26, T10S, R34E, MDB just east of U.S. 395 and 12 miles south of Big Pine (Cleveland, 1958).

### Long Valley, Mono County

Impure diatomite forms a late Pleistocene deposit that crops out discontinuously below thin cover over an area of 50

square miles. Most of the diatomite occurs as a single bed up to 20 feet in thickness centered in the N 1/2 of T3S, R29E, MDB near Little Hot Creek, Casbaugh Ranch and Owens River, 9 miles north-northeast of Mammoth Lakes. The deposit is largely comprised of the genus *Stephanodiscus*, but a

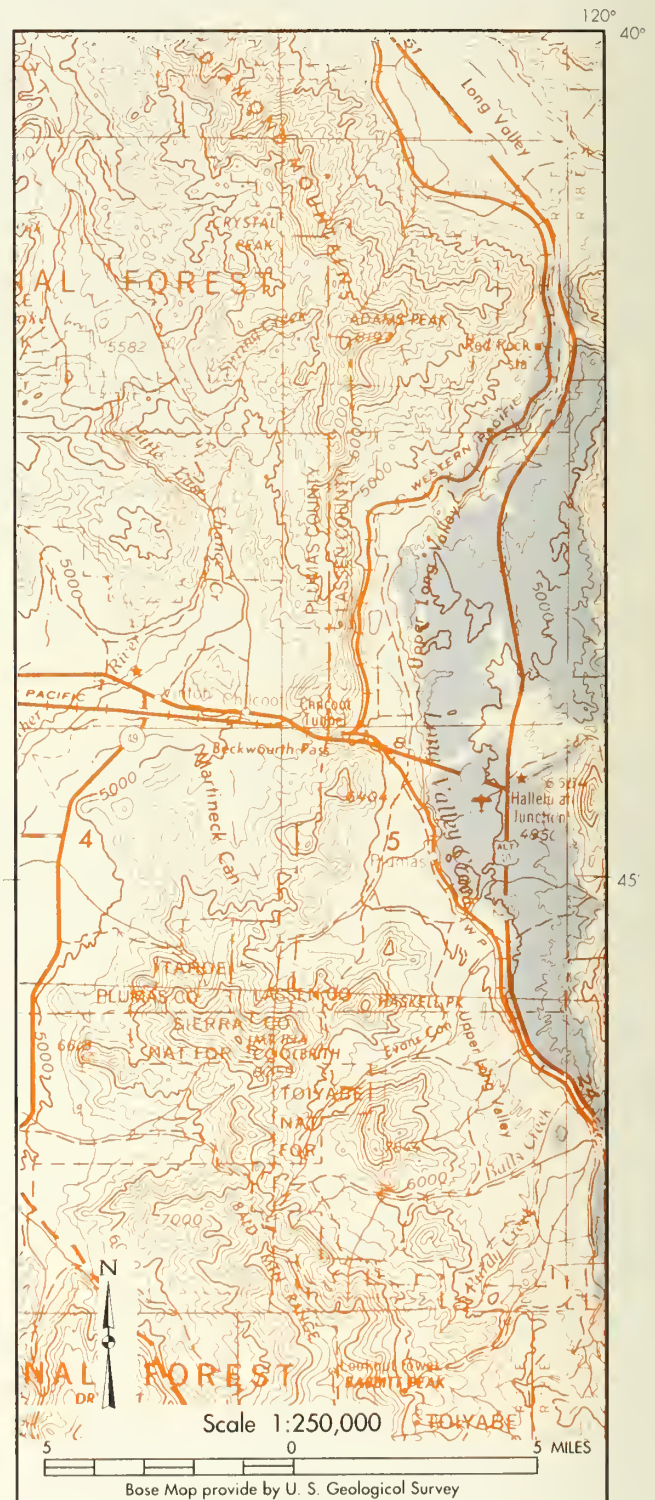


Figure 6. Long Valley diatomaceous shale, Lassen County (Burnett and Jennings, 1962).

large part is contaminated with volcanic ash and calcium carbonate. The deposit contains 7 million tons of low-grade material for use in low specification products (Cleveland, 1961).

#### Long Valley, Lassen County

Six miles north of Hallelujah Junction at Pozola siding on the Western Pacific Railroad is a plant and quarry that was operated by Lassenite Industries until the mid 1980's (Figure 6). The raw material is a thin-bedded diatomaceous shale which dips gently ( $10^\circ$ ) to the north. The beds were derived from a large lake during Tertiary time which extended for over 20 miles along the California-Nevada border.

The processed material was sold for pozzolan and absorbents such as sweeping compound. Drilling at the property has identified some 11,000 acres of useable material and probably most of the lakebed could be used for similar products.

#### Boca Reservoir, Nevada County

Freshwater diatomite of probable Quaternary is exposed along the northwestern shore of Boca Reservoir, north of Lake Tahoe (Figure 7). The beds are nearly horizontal, well-bedded and the minimum thickness is 100 feet.

The known resource is large enough to support commercial development but the area is partially developed for summer homes and recreational use.

#### Copco Reservoir Deposits, Siskiyou County

Diatomite deposits around the shore of Copco Lake were mapped by Williams (1949). Subsequent mapping by the Southern Pacific Company (1987) determined that the deposits were up to 100 feet thick and consisted of fresh water diatomite with 25% clay. Unpublished data in the author's file indicates the following estimates:

Volcanic			Iron			
Diatoms	Glass	Clay	Quartz	Feldspar	Oxide	Biotite
50-60%	3-5%	5-7%	10-12%	10-15%	1-2%	1-2%

#### Piute Valley Deposit northwest of Needles, San Bernardino County

A small, potentially economic deposit of diatomite occurs in Piute Valley, near the California-Nevada border. Outcrops are found primarily in Sections 21 and 28, T13N, R19E, SBBM.

The deposit crops out over an area of approximately 1 square mile. The materials consist of diatomite interbedded with minor amounts of sand, silt, and volcanic ash. The sediments are capped by a layer of caliche. The deposit has been gently uplifted and has been dissected by erosion to expose at least 15 feet of diatomite and associated sediments.

The deposit is lacustrine in origin. The deposit is thinly laminated with sand and silt lenses occurring near the top.

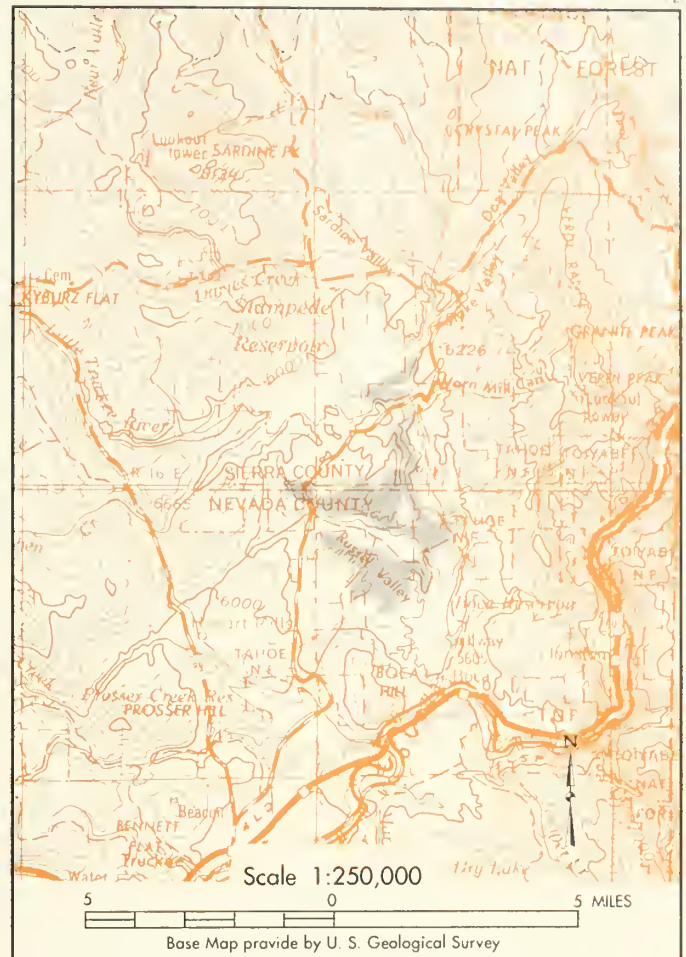


Figure 7. Boca Reservoir diatomite (Burnett and Jennings, 1962)

Diatomite occurs predominantly below this sequence. A cursory examination with the microscope showed approximately 80% diatomite. The beds are nearly horizontal.

Microscopically, the majority of the diatoms are rod-like or cylindrical in shape which is typical of lacustrine diatoms found in the southwest. The individual diatoms are intact and show little or no alteration. The material from the deposit has been used in the past as filler for wallboard and as insulation material (Unruh and Ruff, 1982).

#### White Christmas Deposit near Ocotillo, Imperial County

The deposit is two erosional remnants of Holocene lacustrine diatomite. The northernmost is near the NE 1/4 of Section 11, T17S, R9E, SBM. The body is 12 feet thick, 150 feet long north to south, and 60 feet wide east to west. The southern deposit is 200 feet long and 50 feet wide. The lower half is the purest, although the entire layer contains some volcanic ash, quartz, feldspar and mica (Morton, 1977).



**Northeastern California including Modoc, Lassen, eastern Siskiyou and northeastern Shasta counties**

This large region contains extensive diatomite and diatomaceous shale deposits which have not been commercially developed. In general, these deposits are less pure than the best material found at Lake Britton, but careful exploration drilling could prove the scattered surface exposures to be representative of that found in the subsurface. In addition, in some applications of diatomaceous shale, such as the material used as absorbents, a mixture of diatoms and clay is beneficial.

The region contains broad, flat valleys separated from each other by upfaulted mountain ranges. Some of these valleys contain closed lake basins, such as Lower Klamath Lake and Goose Lake, where diatomite deposits are forming on their floors today. Other basins have been modified by pasture, agriculture and water development so that the past shallow lake has been replaced with very productive ranches and farms.

In the geologic past, lakes were formed in some valleys when their outlets were dammed by faulting or lava flows, forming broad shallow bodies of water similar to Lower Klamath Lake. Under these conditions, diatoms flourished and

formed thick deposits on the lake floor. Most of these deposits can only be assessed by subsurface drilling, although some evidence as to what is present at depth can be determined from near-surface road and stream cuts and examination of the surrounding mountain ranges.

The only regional references to the lakebeds in northeastern California are the Alturas and Westwood sheets of the State Geologic Map of California (Gay and Aune, 1958; Lydon and others, 1960). These maps will be reproduced as illustrations and used as references in this report.

**1. Lower Klamath Lake, Big and Little Tableland and Willow Creek Valley.**

This area is unusual in several respects. The original lake has been maintained as a National Wildlife Refuge although the eastern half dries out in periods of drought. Along the southeastern boundary of the basin at the Tablelands and Willow Creek Valley, argillaceous diatomite exposed along faults are similar to deposits thought to lie at depth below Lower Klamath Lake (Figure 8).

The diatomite at the Tablelands and Willow Creek contains minor amounts of volcanic glass (5%) and clay (2%) with lesser quantities of detrital quartz, feldspar, iron oxides and chlorite. The deposit is well-bedded with individual beds

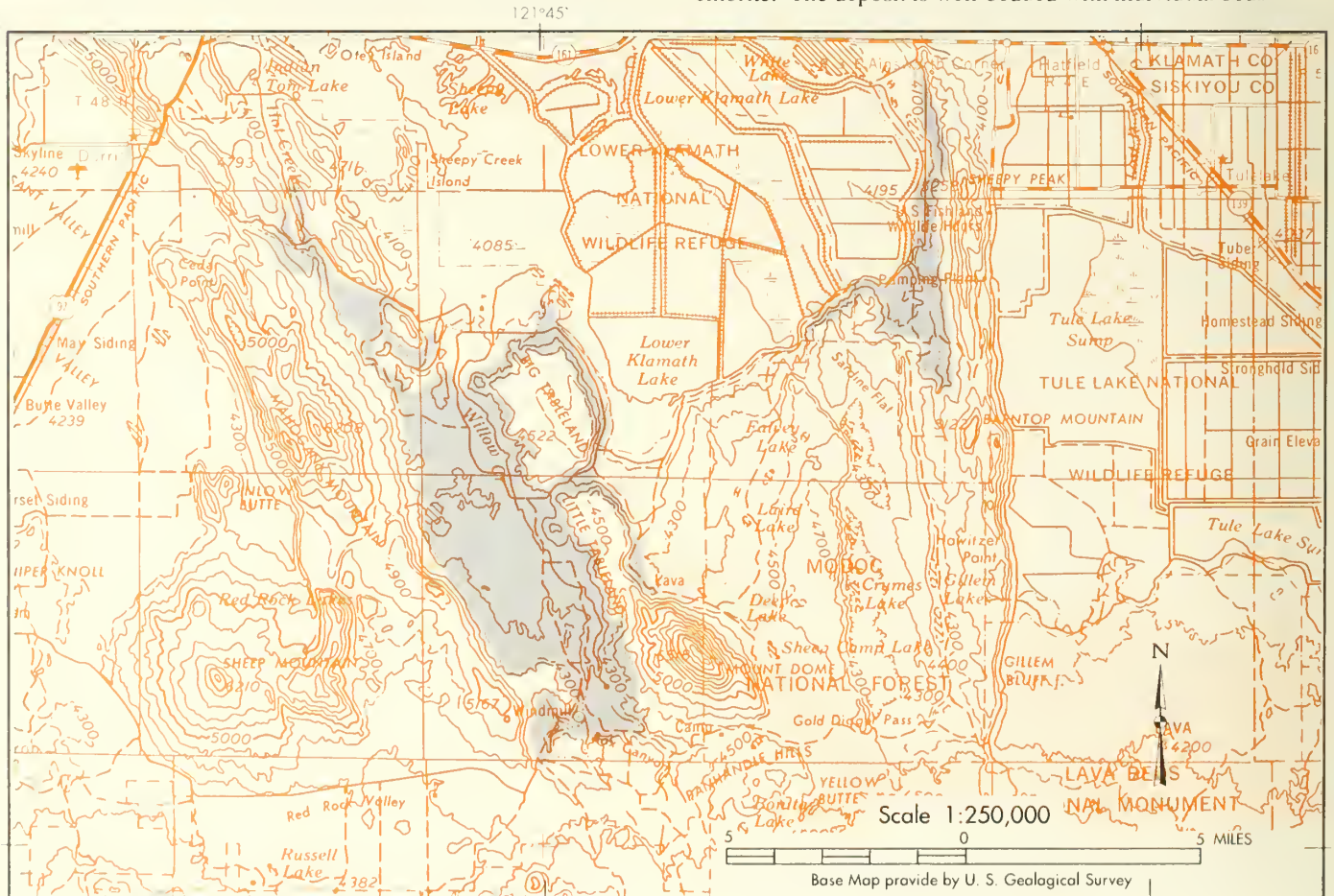


Figure 8. Tablelands, lower Klamath Lake diatomite (Gay and Aune, 1958)



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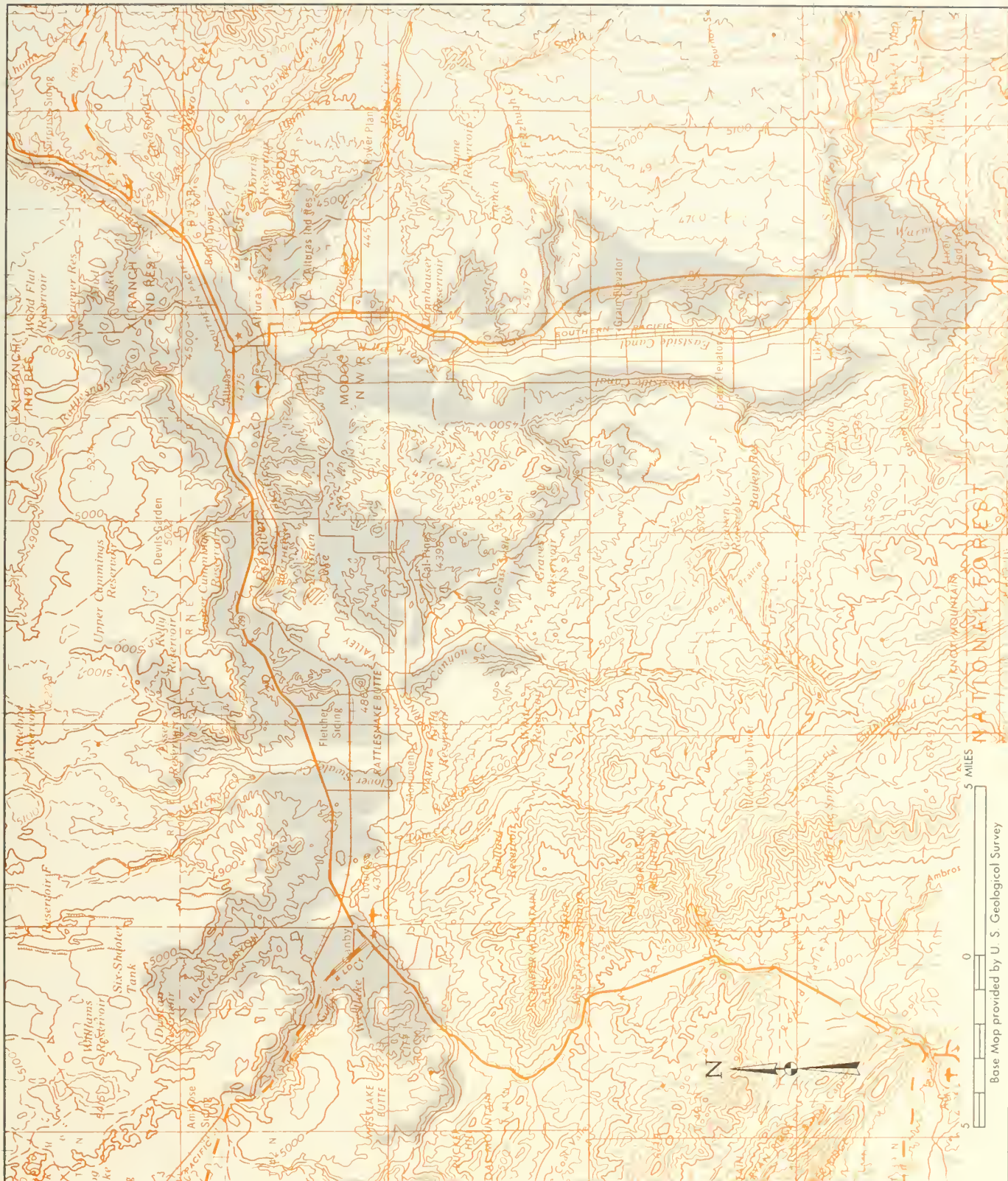


Figure 9. Modoc, Lassen, and Shasta counties' diatomaceous sediments (Gay and Aune, 1958).

ranging from 1 to 12 inches in thickness. Little can be seen of the diatomite under Lower Klamath Lake because the basin is covered by 3 to 4 feet of humus-rich soil; however, the drainage canals sometimes penetrate into pure diatomite with properties similar to that exposed at the Tablelands. The depth of these deposits is unknown because the base is not exposed. Two hundred feet can be seen at the Tablelands and an equal amount of depth is a reasonable expectation. The total reserves here are measurable in cubic miles, not in cubic yards.

*2. The Valleys containing Alturas Valley and Canby Valley, Big Valley and Fall River Valley, Modoc, Lassen and Shasta counties.*

Here again the only evidence of diatomite seen at the surface is in the mountain ranges surrounding these valleys (Figure 9). There is little doubt that lakes occupied these valleys in the geologic past or that these lakes have only recently been drained by the downcutting of the Pit River. The lakebeds near Alturas have been formally named the Alturas Formation; similar rocks in the other valleys have been called "Alturas-type" and this informal usage will be followed here because these basins were not necessarily connected and may have formed in different geologic times.

The lakebeds of the Alturas Formation differ from those at Lower Klamath Lake in purity and are diatomaceous claystones with a significant percentage of clay and volcanic glass. Exposures toward the south in this basin contain lower amounts of diatoms. Exposures southeast of Canby and near Likely are normal clay shales containing few diatoms. Materials exposed near Alturas and Canby are the purest.

Big Valley containing the towns of Adin, Bieber and Nubieber is underlain by "Alturas-type" shales as well as recent lakebeds in the flat marshy center of the valley.

Fall River Valley contains similar recent lakebeds as well as excellent exposures of older diatomaceous shale in roadcuts along Highway 299 east of MacArthur.

It is likely that all three of these valleys are underlain by diatomaceous shale that could be utilized in products that do not require pure diatomite.

*3. Karlo siding, 17 miles south of Ravendale and 3 miles due west of U.S. 395*

Secret Valley is underlain by Tertiary lakebeds which crop out in few areas but are exposed at Karlo siding and the left abutment of a reservoir dam at nearby Biscar Wildlife Area. Forty feet of buff-colored, flat-lying, well-bedded argillaceous diatomite are exposed where the diatomite has been disturbed by construction of the dam. The depth of the diatomite is not known but several hundred feet is a reasonable estimate.

*4. Other localities*

There are many sediments in northeastern California that are rich in diatoms but, for various reasons, are not of commercial interest at the present time. Although not economically important, they may provide some clues to materials in the subsurface. Localities include:

Rices Canyon, 6 miles east of Susanville—diatomaceous, fine-grained sandstone and shale.

The island in Honey Lake—diatomaceous shale and sandstone exposed in wave-cut bluffs.

Smoke Creek Ranch Road, northeast of Susanville and east of Highway 395—diatomaceous claystone covers the valley floor.

Weed Valley, 15 miles west of Goose Lake and 4 miles south of the Oregon border—an erosional "window" in the basalt of the Devils Garden exposing Alturas Formation diatomaceous shale.

Dixie Valley, 15 miles southwest of Hayden Hill—diatomaceous claystone covers the valley floor.

Widow Valley, 8 miles northwest of Beiber—a 30-foot layer of diatomite exposed in a roadcut of Widow Valley Road.

Day, 4 miles northwest of the town—several 10-foot layers of diatomite. Exploration drilling here penetrated over 300 feet of diatomite in the subsurface.

## OTHER DEPOSITS

### **Knights Ferry, Stanislaus County and Friant, Fresno-Madera County**

These two localities are similar in that they both consist of pumicite deposits that locally are more or less diatomaceous. Both have been mined and Friant was an important source of pozzolan for many years.

Although the deposits in these two areas are volcanic pumicite, pozzolanic materials can still be produced here which can compete with pozzolans made from diatomite. Several other similar materials from other localities on the eastern side of the Great Valley are noted by Chesterman (1956).

### **Getty Oil Diatomite Project near McKittrick, Kern County**

This project is a pilot plant begun in 1972 to investigate the economic feasibility of recovering petroleum from an oil-saturated diatomaceous shale in the McKittrick Oil Field northwest of McKittrick in Kern County.

The deposit consists of diatomaceous and siliceous mudstones, chert, tuffaceous and carbonate rocks, asphaltites and breccias. It is an extensive deposit of Antelope shale in upper



Miocene Monterey Formation diatomite and related siliceous deposits. Numerous tar seeps are present on the property which are surface evidence of an estimated 832 million barrels of probable in-place oil.

Two pilot plants were built to test petroleum extraction by retorting and by solvent extraction (Mulhern and others, 1983). The plant closed in the mid 1980's when oil prices became unstable and there was a general slowdown in the petroleum industry. The solvent extraction pilot plant has been removed and all operations have ceased (1990).

## RESERVES

Diatomite resources are difficult to describe because diatomaceous rocks underlie large areas and include strata of various qualities. The diatomite resources and reserves of California, where most of the world's diatomite is produced, have never been computed and classified according to grade. However, diatomite resources of the United States are adequate to allow for a steady increase in diatomite production. The abundance of the material is evident, for example, considering only those reserves controlled by one diatomite producing company at Lompoc, California. This deposit covers an area of 3-4 square miles and is workable to a depth of 700 feet (Industrial Minerals, 1969, p. 14), which suggests that it could supply world needs for diatomite at the current rate of consumption for several hundred years. On the other hand, factors such as proximity to markets and suitability of the material for specific uses enter into the evaluation of diatomite resources; the location and quality of diatomite deposits seem to be more important factors in the economics of diatomite production than is the amount of material available (Durham, 1973).

## CALIFORNIA PRODUCTION

The commercial value of diatomite was not recognized until the late 1880's when a small amount was mined from the deposits at Lompoc for building stone. In 1889, production records show that 39 tons of diatomite were mined from deposits near Calistoga in Napa County. During the 1900's, only a few hundred tons were mined annually in California, but the material was being tested for use in insulation, filtering and beet sugar refining. The latter use became the foundation of the modern diatomite industry. Suitability for filter application has been a prime consideration in the evaluation of any diatomaceous earth deposit planned for large-scale exploitation.

The Lompoc deposits were being actively developed at the turn of the century and beginning in 1904, the deposits in Monterey County were developed. At the time of World War I, California's annual production had reached about 13,000 tons.

The diatomite industry developed rapidly after World War I from an important statewide industry, to one of national and even international significance. The Johns-Manville Corporation acquired a large part of the Lompoc deposits in 1928, and in 1930 the Dicalite Company opened the extensive deposits in the Palos Verdes Hills in Los Angeles County. The industry was consolidated by a few large corporations during the 1940's and with the stimulus of World War II and industrial expansion since then, a steady rise in both tonnage and average price has been recorded. The Dicalite Company acquired deposits near Lompoc in 1942 and in 1944 the company was purchased by the Great Lakes Carbon Corporation. Mining of diatomite near Bradley, in Monterey County, ceased in 1942 after nearly \$500,000 worth of material had been produced by the Pacatome Company. The Palos Verdes Hills deposits near Waleria were abandoned in 1958 due to encroaching urbanization and depletion of ore reserves.

Although some effort was made toward the commercial production of diatomite in other counties during the period 1947-1955 (Oakshott, 1957), by 1955 only the major deposits at Lompoc were being operated by Johns-Manville Corporation and Dicalite Division of Great Lakes Carbon Corporation. In the period from 1955-1980, diatomite production increased appreciably in the Lompoc area and minor production was contributed by operators in Napa, Kern, and Lassen counties (Taylor, 1981).

## UTILIZATION AND PRODUCTION

Because diatomite consists of billions of minute silica frameworks, the material has many unusual properties. The frustules are strong and support intricate internal frameworks with maximum void space resulting in bulk densities as low as 0.1 or 0.2. The siliceous framework is chemically inert and resistant to high temperatures. The small size of the open pores gives diatomite excellent capillary attraction making it a good absorbent. The material has an extremely high surface area per unit of volume, commonly in the order of thousands of square yards per ounce of diatomite.

Diatomite has hundreds of specific uses in 11 categories:

1. filters
2. fillers
3. insulating materials
4. mild abrasives
5. absorbents
6. catalyst carriers
7. reactive-silica source
8. structural materials (lightweight aggregate)
9. additive for concrete (pozzolan)
10. conditioner or anticaking agent
11. silica component in Portland cement

Most users are dependent on the aggregate effect of the microscopically complex and chemically inert diatom frustules.

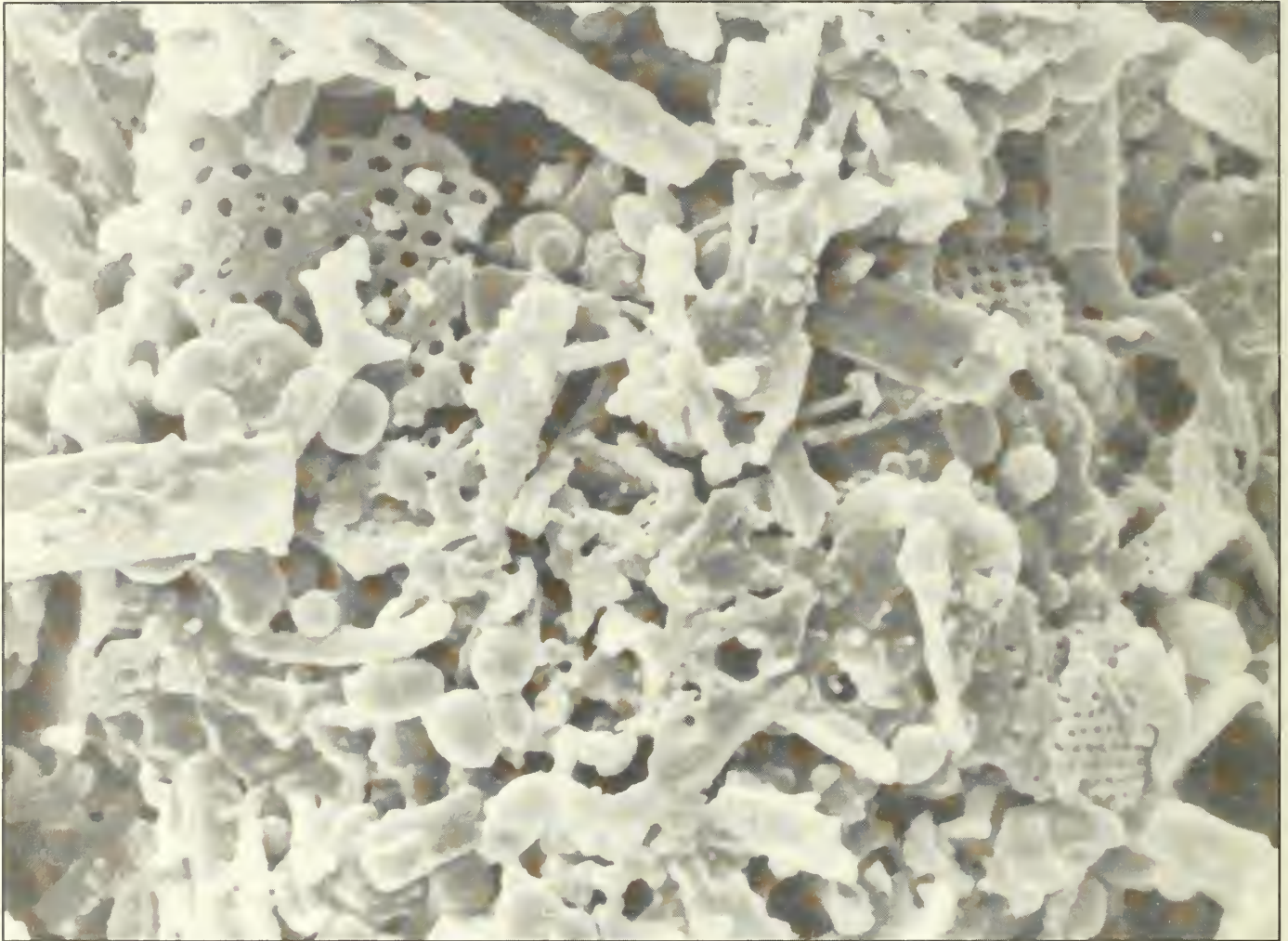


Photo 9. Scanning electron micrograph of yeast cells (round particles) removed by diatomite filteraid in a brewery filter.  
(Photo courtesy of Manville Products Co.)

Aside from its light weight and porosity, other characteristics of diatomite make it suitable for industrial uses (Photo 9). Diatomite has a low thermal conductivity and a melting point that ranges between 1,400° and 1,750°C, although certain impurities can result in a considerably lower melting point. The opaline silica of diatomite is nearly chemically inert and is soluble in industrial applications only in hydrofluoric acid and strongly alkaline solutions, so diatomite is especially useful as a filler (Durham, 1973).

Most of the California production comes from the Lompoc area of Santa Barbara County although substantial production comes from the Lake Britton deposits in Shasta County. Competing diatomaceous products are produced at Mina, Sparks, Fernley and Lovelock, Nevada; Vale and Christmas Valley, Oregon; Quincy, Washington; and Mammoth, Arizona (Davis, 1990).

Commercial diatomite has porosity as high as 95% voids with 60 million diatoms per cubic inch. It will readily absorb 2 1/2 times its weight in water (Craig Smith, personal communication, 1990).

The apparent density of the processed powder is about 10 pounds per cubic feet whereas a cubic foot of solid opal weighs 135 pounds. Less than 1/2 pound of the processed diatomite has a surface area equal to that of a football field (45,000 square feet).

The size of most diatoms is in the micron range (1 micron = 1/1,000,000 meter) although the larger species can be seen with the naked eye. Classification of diatoms into species is based on shape and ornamentation, and many thousands of species have been differentiated on the basis of frustule morphology.



TABLE 6. Comparison of U. S. Diatomite Production and Demand 1963-83, 1990, and 2000 (thousand short tons)

YEAR	U.S. PRIMARY DEMAND	U.S. PRIMARY PRODUCTION
1963	431	543
1964	435	563
1965	470	584
1966	463	607
1967	494	625
1968	474	646
1969	422	598
1970	444	598
1971	390	535
1972	430	576
1973	433	609
1974	482	664
1975	430	573
1976	487	631
1977	497	648
1978	498	651
1979	548	717
1980	516	689
1981	525	687
1982	472	613
1983	473	619
1990 (est.)	570	725
2000 (est.)	750	900

From Meisinger (1985)

Because of the diversity of sizes and shapes of diatoms, different blends can be formulated to remove almost any kind of material from a liquid. Blends can be created to filter at high and low rates of flow. Each filter aid user must balance the opposing factors of:

1. Clarity of the final product. How small a particle size must be removed to produce an acceptable product?
2. Flow volume. How much liquid must be sent through the filter system to produce an economically viable product?

Diatomite filter aids are manufactured in various grades to remove particles down to the following micron sizes:

0.1 micron	0.8 micron
0.5 micron	1.1 micron
0.65 micron	

The milling and classifying techniques used to create these specialized products are carefully guarded company secrets.

Pure, undiluted deposits of diatoms produce the highest value material as filter aids and abrasives; after carefully engineered milling, high-dollar value products are created. Most of the uses for diatomite can tolerate much less pure raw material. Absorbents, including cat litter and sweeping compounds, utilize diatomaceous shale or mudstone. The diatom content is variable but the usefulness of the product is enhanced by smectite (montmorillonite or bentonite) clay which is also a powerful absorbent. These diatom-smectite mixtures can be made more absorbent by driving off interlayer water within the clay.

Pozzolans and lightweight aggregates can be produced from impure smectite-diatomite mixtures using high temperatures so that both interlayer and crystalline water are driven off and, in some cases, the melting point is approached.

There are other raw materials that compete with diatomite in the field of filter aids as well as other products. Perlite, a glassy volcanic rock with the chemical composition of rhyolite, is superior to diatomite in some filter aid applications (Photo 10). The perlite must first be expanded by a milling process where the crushed perlite is rapidly heated to near its melting point at 1,500°F to 2,000°F. At these temperatures, water naturally converts to steam, forming bubbles of glass which pop like popcorn and form hollow, broken glass shards. These shards are then quickly cooled in a column of moving air so that the individual particles do not adhere to one another. The finished expanded perlite weighs 20% less per unit of volume than standard diatomite filter aids and results in comparable savings in some uses. Perlite is also highly efficient in handling fluids with high solid content and causes less cake cracking on rotary vacuum precoat filters.

Another competitor in some applications is cellulose, the fibrous vegetable material. Cellulose filter aids are especially useful in situations where traces of soluble silica cannot be tolerated, such as metal plating solutions and chemicals, and steam condensates from boilers. The cellulose fibers bridge well over the filter mesh support and will maintain the coating when vacuum or pump pressure is removed.

Within the pozzolan market, fly ash is a very significant competitor with products made with natural diatomite. Fly ash is the silica-rich waste product created from the smoke-stack gases of coal-fired electric generating plants. Fly ash

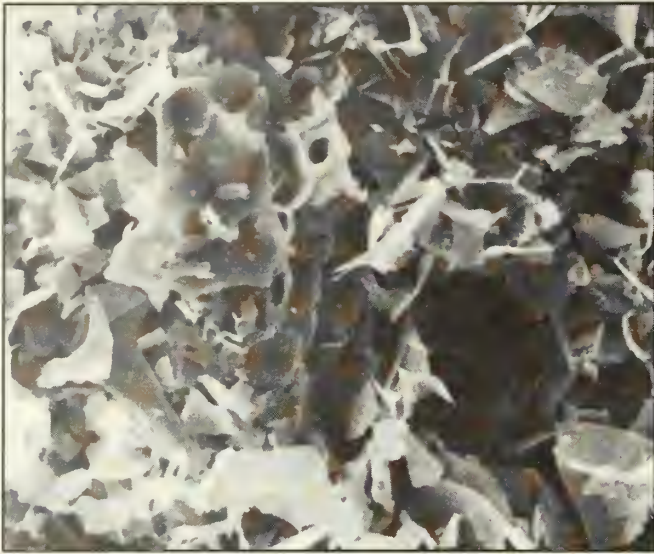


Photo 10. Perlite, 500x scanning electron micrograph. For some applications, this material competes with diatomite. (Photo courtesy of Manville Products Co.)

has some economic advantages over manufactured pozzolans in that:

1. It is a waste product that is produced in large quantities whether it can be used or not.
2. In an effort to dispose of this material, the federal government has set up regulations which favor the use of fly ash on federally funded projects.

The result of these advantages is that fly ash pozzolan can be delivered to market at a lower cost than manufactured pozzolan even though it must be transported hundreds of miles farther. In the case of federal projects, it may be required by specification to the disadvantage of diatomite sources.

## MARKETS

Finished diatomite from California is shipped all over the United States and exported to all continents. Much of the material that is exported goes to Japan and western Europe, particularly West Germany, Belgium, and Holland. Most diatomite used in California is shipped to the Los Angeles and San Francisco areas and various food and wine-processing centers and sugar refineries in the central and coastal valleys.

## MINING

Although limited underground mining methods have been used in the past, all United States deposits are mined today by surface mining methods which are similar among all companies. Overburden is removed, crude ore is ripped by a bulldozer and then picked up by a beltloader or front-end loader. It is seldom necessary to use explosives. The open-pit quar-

ries are mined in benches if the deposit is deep and the material is stockpiled according to purity, color and density. Even small, 2-to-6 inch thick layers of impure material may be selectively removed so that they will not enter the feed to the mill.

Other products such as absorbents and pozzolan have less critical requirements for their raw materials although they do maintain careful quality control to meet the needs of their products. Again, earth moving equipment is used in these open-pit quarries.

## BENEFICIATION

Depending on the final product being produced, milling methods vary widely among different processing plants. Nearly all plant circuits include crushing and screening to reduce the mined material to a manageable size. Fines which pass through the screens are often discarded as waste. In order to produce a uniformly fine-grained product, a grinding stage in a ball mill may be included. Most processes require drying. Because diatomite is a natural absorbent, water from surface and subsurface natural flow must be driven off by heat so that all of the raw material feed can be handled in a uniform manner. In some areas, air drying in the sun can be utilized. Otherwise, a rotary kiln is used.

The two plants at Lompoc utilize the highest processing technology found anywhere in the industry. Their procedures involve a series of basic crushing and drying steps developed and refined over the years to preserve the diatom skeletal structure, a unique physical property that sets the commodity apart from other forms of silica. The principal products are aggregates and powders of various sizes of uncalcined, straight-calcined, or flux-calcined grades.

Uncalcined ("natural" grade) diatomite processing comprises crushing the material to aggregate size followed by a simultaneous milling-drying cycle as the suspended particles are carried in a stream of hot gases. The suspended particles and impurities are sized and removed through a series of cyclone classifiers, leaving the variously sized products to be collected in a baghouse for market preparation.

For filtration uses, natural-grade diatomite is calcined in large rotary kilns, with or without a fluxing agent. The calcination process removes organic matter and moisture and converts impurities into a fused slag that can be extracted later by air classification. The resultant straight-calcined product is usually applied to filter uses where medium flow rates are required. For faster flow rates, a fluxing agent, such as soda ash, is added to the kiln feed in order to sinter the particles to increase their size. This product is the flux-calcined grade.

Filter aid powders for special uses are produced by acid treatment of dried and milled material in combination with the calcination process (Meisinger, 1985).



The specific details of processing filter aids, abrasives and other such products are proprietary and are not released publicly. The very precise specifications that are achieved routinely in the final product testify to the level of technology that is used in the manufacturing process.

## EVENTS, TRENDS AND ISSUES

### Reclamation

Ultimate reclamation of active mines at the end of their productive lives is a high priority today in California and many other parts of the country. To be legally closed, a mine must be restored to a safe beneficial end use that is readily adaptable to alternate uses. Diatomite and diatomaceous shale are not toxic in any way to plants or animals. Both disturbed and undisturbed diatomite have a high capacity to retain moisture which facilitates revegetation. A vegetation cover is important to control erosion and in some cases, re-establish habitat for wildlife.

Los Angeles County has an outstanding example of reclaiming a closed diatomite quarry on the Palos Verdes Peninsula at WALTERIA. Grefco Inc. operated the quarry from 1929 to 1956, producing over 1 million tons of diatomite. Following closure, the site was used as a sanitary landfill by Los Angeles County. From 1957 to 1965, 3 1/2 million tons of trash were buried until encroaching urbanization forced the landfill's closure. Beginning in 1961, the county began to create the South Coast Botanic Garden over the landfill. Today the garden has over 2,000 species from all over the world and specializes in varieties from Australia and southern Africa, whose similar native climates allow these plants to thrive there.

### Urban Growth and Parklands

A significant problem with diatomite in the past quarter century has been the loss of resources due to urban growth. Urbanization has eliminated any possibility of diatomite mining in most parts of Ventura, Los Angeles and Orange counties in southern California; smaller but similar losses have taken place in the urbanized parts of northern California.

Northeastern California has extensive reserves of freshwater diatomite which are not threatened by urbanization, but which could be affected by future development of parks or wilderness areas.

### Potential Health Risk

A potential problem facing the diatomite industry, and other mineral industries, is evaluation of the health risk of crystalline silica (Miles, 1990). In 1988, the International Agency for Research on Cancer (IARC), part of the World Health Organization of the United Nations, classified crystalline silica as a probable carcinogen. This prompted the regulation of crystalline silica at a threshold concentration of 0.1% in materials controlled by the Federal Hazard Communication Act, which requires warning labels and special handling of products containing crystalline silica.

The minerals classified as crystalline silica, in decreasing order of possible health hazard, are tridymite, cristobalite and quartz. The possible health hazard of opal, which is amorphous and not crystalline silica, is uncertain at this time (1990).

The test results of IARC have been published in a series of monographs; the volume dealing with the most recent studies on crystalline silica was released in 1987 (International Agency for Research on Cancer, 1987). In the preamble of this monograph, the objective makes no recommendations concerning legislation but presents a critical review of data on carcinogenicity and indicates where additional research efforts are needed.

At this time, it is uncertain what regulations will be adopted by both the United States and California governments with regard to crystalline silica.

## ACKNOWLEDGMENTS

Pioneering work on diatomite localities in northeastern California was done between 1949 and 1955 by G Dallas Hanna, California Academy of Sciences, and Charles W. Chesterman, Division of Mines and Geology. This work was followed in the late 1950's by that of Quintin A. Aune, Division of Mines and Geology and in the mid 1980's by that of Platt Bradbury, U.S. Geological Survey.

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## APPENDIX

### Location of diatomite quarries and localities.

#### Imperial County

White Christmas Deposit  
Ownership not determined  
T17S, R9E, Sec. 11 SBB  
Latitude - 32.702 degrees N  
Longitude - 116.035 degrees W  
Unpaved road southwest of Ocotillo and State Highway 98.

#### Inyo County

Poverty Hills Diatomaceous Earth Deposit  
Ownership not determined  
T10S, R34E, Sec. 23 and 26, MDB  
Latitude - 37.057 degrees N  
Longitude - 118.230 degrees W  
The deposit is east of U.S. Highway 395 near the west (or right) abutment of Tinemaha Reservoir.

#### Kern County

Excel-Mineral Co. Inc.  
P.O. Box 1277  
Taft, CA 93268

1. McKittrick Pit  
T30S, R21E, Sect 4 and 5, MDB  
Latitude - 35.355 degrees N  
Longitude - 119.725 degrees W  
From State Highway 33 turn west on Lokern Road; turn south on Lost Hills Road; at Chevron Field Office turn west on unnamed road to pit. This quarry was closed and reclaimed in 1989.

2. Taft Pit  
T32S, R23E, Sec. 28, MDB  
Latitude - 35.110 degrees N  
Longitude - 119.508 degrees W  
5 miles west of Taft

Getty Oil Company  
P.O. Box 85  
McKittrick, CA 93251

McKittrick Diatomite Deposit  
T30S, R21E, Sec. 13, MDB  
Latitude - 35.317 degrees N  
Longitude - 119.675 degrees W  
2 miles northwest of McKittrick on Reward Road.  
Lowe's Southern Clay of California, Inc.  
348 S. Columbia St.  
South Bend, Indiana 46601

Lowe's Clay Quarry  
T11N, R24W, Sec. 9, MDB  
Latitude - 35.063 degrees N  
Longitude - 119.437 degrees W  
2 miles south of Maricopa on State Highway 33 to Elkhorn Grade Road; west to signed quarry road.

#### Lassen County

A and M Trucking, Inc.  
P.O. Drawer 112  
Yuba City, CA 95992  
Lassenite (Pozola) Quarry  
T23N, R17E, Sec. 11, MDB  
Latitude - 39.861 degrees N  
Longitude - 120.041 degrees W  
6 miles north of Hallelujah Junction, west of and adjacent to U.S. 395.

#### Mono County

Long Valley Diatomaceous Earth Deposits  
Ownership not determined  
The diatomite bed covers a considerable area centered on the north half of T3S, R29E, MDB  
Latitude - 37.683 degrees N  
Longitude - 118.810 degrees W  
Access is to the east of U.S. Highway 395 via Antelope Springs Road and Benton Crossing Road near Mammoth Lakes.

#### Monterey County

Hames Valley Diatomite Deposits  
Ownership not determined  
T24S, R10E, Sec. 8, 9, 10 and 15, MDB  
Latitude - 35.852 degrees N  
Longitude - 120.887 degrees W  
Exit U.S. Highway 101 at Jolon Road north of Bradley; access to deposits via private roads off Jolon Road and Nacimiento Lake Drive.

#### Nevada County

Boca Reservoir Diatomite Deposits  
Ownership not determined  
T18N, R17E, Sec. 5, 6, 7, 8, 9 and 16 MDB  
Latitude - 39.419 degrees N  
Longitude - 120.096 degrees W  
Access via Hobart Mills Road and Russel Valley Road northeast of Hobart Mills.



## San Bernardino County

Piute Valley Pit  
Ownership Unknown  
T13N, R19E, Sec. 21 and 28, SBB  
Location not field verified.

## Santa Barbara County

Airox Quarry and Plant  
Present Ownership Unknown. The property is abandoned.  
Undivided land, no township, range and section network.  
Latitude - 34.867 degrees N  
Longitude - 120.517 degrees W  
Take Black Road southwest from its junction with State Highway 1 southwest of Santa Maria; 1 mile from junction,  
Airox Road bears left 1 mile to quarry and plant.

Grefco Inc.  
1515 E. Chestnut Ave.  
Lompoc, CA 93436

Grefco Quarry  
Undivided land  
Latitude - 34.583 degrees N  
Longitude - 120.283 degrees W  
South on State Highway 1 from Ocean Ave. in Lompoc, 5.8 miles; quarry road is to the left and signed.

Manville Products Co.  
2500 Miguelito Road  
Lompoc, CA 93436

Manville Quarry  
T6N, R34W, projected, undivided land  
Latitude - 34.617 degrees N  
Longitude - 120.450 degrees W  
South from downtown Lompoc on I Street to Miguelito Road. Follow this to signed quarry entrance.

N.T.U. Mine  
Land owner: Casmalia Resources  
P.O. Box 208  
Casmalia, CA 93429  
Mineral rights owner: Union Oil Corporation  
T9N, R35W, Sec. 3, SBB  
Latitude - 37.931 degrees N  
Longitude - 120.553 degrees W  
North of Casmalia on Black Road 1 mile to N.T.U. Road; left on N.T.U. Road to Casmalia Resources gate and office.  
Permission must be obtained to enter.

## Shasta County

American Resources Equity Corporation  
5500 S. Syracuse Circle, #201  
Englewood, Colorado 80111

American Resources Diatomite Quarry  
T36N, R3E, Sec. 12, MDB  
Latitude - 40.995 degrees N  
Longitude - 121.588 degrees W  
From junction of State Routes 299 and 89 east of Burney, drive north several miles to point where railroad crosses highway; backtrack 0.5 miles to paved road going northeast (left); scale house is 2.9 miles on this road.

Grefco Inc.  
1515 E. Chestnut Ave.  
Lompoc, CA 93436

Dicalite Quarry  
T37N, R2E, Sec. 25 and 36, MDB  
Latitude - 41.031 degrees N  
Longitude - 121.683 degrees W  
From State Route 89 south of Burney Falls State Park take Clark Creek Road to the northwest (right); cross dam to junction of 5 roads; take road at right angles to left; go 0.5 miles to gate.

## Siskiyou County

Copco Reservoir Diatomite Deposit  
Ownership not determined  
T48N, R4W, Sec. 21, 27, 28, 35 and 36, MDB  
Latitude - 41.982 degrees N  
Longitude - 122.297 degrees W  
Access east of Interstate 5 near Hornbrook via Copco Road (north shore of Copco Lake) or Ager-Beswick Road (south shore of Copco Lake).







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